

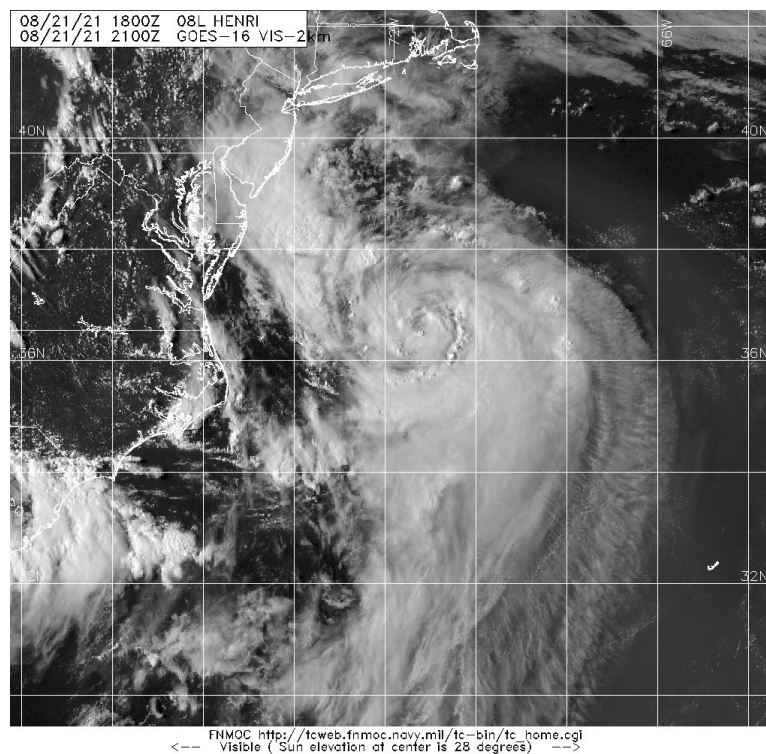


NATIONAL HURRICANE CENTER TROPICAL CYCLONE REPORT

HURRICANE HENRI (AL082021)

15–23 August 2021

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National Hurricane Center
25 January 2022



GOES-16 VISIBLE SATELLITE IMAGE OF HURRICANE HENRI AT 2100 UTC 21 AUGUST 2021. IMAGE COURTESY OF NAVAL RESEARCH LABORATORY

Henri was a category 1 hurricane (on the Saffir-Simpson Hurricane Wind Scale) that followed an unusual track over the western Atlantic, eventually making landfall in Rhode Island as a 55-kt tropical storm. Henri caused extensive flooding in parts of the northeastern U.S., and there were 2 surf-related drownings in North Carolina.

Hurricane Henri

15–23 AUGUST 2021

SYNOPTIC HISTORY

Henri was of non-tropical origin. A cluster of thunderstorms associated with a mid-level disturbance moved off the U.S. Mid-Atlantic coast late on 11 August and early on 12 August. Deep convection associated with this system temporarily diminished, but its thunderstorms increased early on 13 August a few hundred n mi southeast of southeastern Massachusetts. The disturbance generated a weak surface trough a few hundred n mi north-northeast of Bermuda on 14 August, and this trough evolved into a surface low pressure system by 0000 UTC 15 August, centered a little over 200 n mi north-northeast of Bermuda. While the low moved slowly south-southeastward, deep convection gradually became better organized in a few bands over the southern portion of the circulation. Around 1800 UTC 15 August, the system's convection became sufficiently organized to designate the formation of a tropical depression, centered about 150 n mi northeast of Bermuda. The "best track" chart of the tropical cyclone's path is given in Fig. 1, with the wind and pressure histories shown in Figs. 2 and 3, respectively. The best track positions and intensities are listed in Table 1¹.

The cyclone moved southward to south-southwestward on the eastern side of a mid-level high pressure area over the western Atlantic, and gradually strengthened into Tropical Storm Henri around 1800 UTC 16 August while centered about 110 n mi southeast of Bermuda. Henri turned southwestward on 17 August while strengthening only slowly, likely due to northerly vertical shear and relatively dry air at mid-tropospheric levels which resulted in a lack of deep convection over the northern part of the circulation. Moving around the southern periphery of the mid-level anticyclone, Henri turned westward and strengthened to an intensity of 60 kt by 1800 UTC 18 August. Under the persistent influence of northerly shear and dry low- to mid-tropospheric air, the storm's intensity leveled off, and slight weakening occurred on 19 August while Henri continued westward. Microwave imagery showed some southward tilt of the vortex with height, as the shear increased even a little more that day.

On 20 August, the shear began to relax while the storm turned northwestward and northward ahead of a mid-tropospheric trough/low just inland of the mid-Atlantic coast. The reduced shear and higher oceanic heat content associated with the Gulf Stream resulted in some slight restrengthening, and by 1200 UTC 21 August Henri became a 65-kt hurricane while centered about 170 n mi southeast of Cape Hatteras, North Carolina. The cyclone accelerated

¹ A digital record of the complete best track, including wind radii, can be found on line at <ftp://ftp.nhc.noaa.gov/atcf>. Data for the current year's storms are located in the *btk* directory, while previous years' data are located in the *archive* directory.

north-northeastward on 21–22 August toward the northeast U.S. coast, on the east side of the mid-level low. After moving north of the Gulf Stream, Henri weakened below hurricane strength by 1200 UTC 22 August, and it made landfalls on Block Island and near Westerly, Rhode Island around 1520 and 1615 UTC, respectively, on 22 August as a 55-kt tropical storm. Slowing in forward speed while turning westward around the northern part of the mid-level low, the system weakened rapidly over southern New England, and Henri was reduced to a tropical depression over western Connecticut by 0000 UTC 23 August. After moving into southeastern New York, the weakening cyclone looped back into Connecticut late on 23 August, where it degenerated into a remnant low. The system then headed east-northeastward over Rhode Island and southeastern Massachusetts on 24 August, and moved back over the western Atlantic where it dissipated late that day.

METEOROLOGICAL STATISTICS

Observations in Henri (Figs. 2 and 3) include subjective satellite-based Dvorak technique intensity estimates from the Tropical Analysis and Forecast Branch (TAFB) and the Satellite Analysis Branch (SAB), objective Advanced Dvorak Technique (ADT) estimates and Satellite Consensus (SATCON) estimates from the Cooperative Institute for Meteorological Satellite Studies/University of Wisconsin-Madison. Observations also include flight-level, stepped frequency microwave radiometer (SFMR), and dropwindsonde observations from WC-130 flights of the 53rd Weather Reconnaissance Squadron of the U.S. Air Force Reserve Command and WD-P3 aircraft of the NOAA Aircraft Operations Center. There were 19 center fixes in Henri made by the Air Force C130s, and 5 made by the NOAA P3s. There were also 4 synoptic surveillance flights performed by the NOAA G-IV aircraft.

Data and imagery from NOAA polar-orbiting satellites including the Advanced Microwave Sounding Unit (AMSU), the NASA Global Precipitation Mission (GPM), the European Space Agency's Advanced Scatterometer (ASCAT), and Defense Meteorological Satellite Program (DMSP) satellites, among others, were also useful in constructing the best track of Henri.

Ship reports of winds of tropical storm force associated with Henri are given in Table 2, and selected surface observations from land stations and data buoys are given in Table 3.

Winds and Pressure

Henri's maximum intensity of 65 kt is based on a blend of flight-level winds and SFMR-observed surface winds from Air Force Reserve Unit and NOAA Hurricane Hunter aircraft. The peak surface-adjusted flight-level wind was 74 kt around 1300 UTC 21 August while the maximum observed surface wind around the same time was 55 kt. Later, at 2345 UTC on the 21st, the maximum surface-adjusted flight-level wind was 66 kt and the peak surface wind was 66 kt.

The 55-kt landfall intensity of Henri in Rhode Island is based on 2 surface observations, one from Great Gull Island, New York, of a 1-minute wind of 56 kt at 1600 UTC 22 August, and another from Point Judith, Rhode Island, of a 1-minute wind of 53 kt at 1522 UTC 22 August. Both

of these observations were at an elevation of 16 m, which reduce to 10-m winds of 53 kt and 50 kt at Great Gull and Point Judith, respectively, using an exponential wind reduction formula.

Tropical-storm-force winds associated with Henri occurred mainly in Rhode Island, southern Connecticut, extreme southern Massachusetts, and Long Island. Wind gusts to 61 kt and 60 kt were measured at Point Judith and Great Gull Island, respectively. A sustained wind of 38 kt with a gust to 49 kt was observed at Quonset Point, Rhode Island. Sustained winds of 38 kt with gusts to 49 kt were also measured at the U.S. Coast Guard Academy in New London, Connecticut. A wind gust to 44 kt was observed at the Wall Street Heliport in downtown New York City. Sustained winds of 38 kt and gusts to 45 kt were observed at Baiting Hollow in Long Island, New York. A sustained wind of 45 kt with a gust to 57 kt was measured at Buzzard's Bay, Massachusetts, but this was a significantly elevated (25 m) observing site.

The minimum central pressure of Henri, 986 mb, is based on a dropsonde measurement at 0658 UTC 22 August of 987 mb with 10-kt winds at the surface.

Henri's landfall pressure of 987 mb on Block Island, Rhode Island is based on a surface observation of 987.1 mb from Block Island. The landfall pressure of 988 mb at Westerly, Rhode Island is based on an eye dropsonde pressure of 990 mb with 21-kt winds at 1523 UTC 22 August.

Henri is the strongest tropical cyclone to pass over New England since Tropical Storm Bertha in July of 1996. The last hurricane to make landfall in New England was Bob in August of 1991.

Storm Surge²

The highest measured storm surges from Henri were 2.57 ft above normal tide levels at a United States Geological Survey (USGS) tide gauge at Riverhead, New York, and 2.46 ft above normal tide levels at a National Ocean Service (NOS) tide gauge at Quonset Point, Rhode Island. Higher surges likely occurred between *in situ* water level gauges.

Combined with the tides, Henri's surge resulted in inundation levels as high as 2 to 4 ft above ground level along the north shore of Long Island and the coast of Connecticut (Table 3, Fig. 4). The highest water level recorded by a coastal gauge was by a USGS wave height sensor near the village of Greenport on the North Fork of Long Island, which measured a converted wave-filtered water level of 3.1 ft above Mean Higher High Water (MHHW). A USGS wave height sensor near Greenwich, Connecticut, measured a converted wave-filtered water level of 2.1 ft

² Several terms are used to describe water levels due to a storm. **Storm surge** is defined as the abnormal rise of water generated by a storm, over and above the predicted astronomical tide, and is expressed in terms of height above normal tide levels. Because storm surge represents the deviation from normal water levels, it is not referenced to a vertical datum. **Storm tide** is defined as the water level due to the combination of storm surge and the astronomical tide, and is expressed in terms of height above a vertical datum, i.e. the North American Vertical Datum of 1988 (NAVD88). **Inundation** is the total water level that occurs on normally dry ground as a result of the storm tide, and is expressed in terms of height above ground level. At the coast, normally dry land is roughly defined as areas higher than the normal high tide line, or Mean Higher High Water (MHHW).

MHHW. However, a storm surge simulation hindcast produced by the NHC Storm Surge Unit (not shown) indicated that peak inundation levels up to 4 ft above ground level likely occurred along isolated portions of both the northern and southern shores of Long Island Sound where there were no tide gauges or water level sensors.

Storm surge inundation levels of 1 to 3 ft above ground level occurred elsewhere along the south shore of Long Island and the coasts of Rhode Island and southeastern Massachusetts. Peak water levels measured in these areas include 2.2 ft MHHW near East Hampton, New York; 2.3 ft MHHW near Narragansett, Rhode Island; and 1.7 ft MHHW at several locations in southeastern Massachusetts.

Rainfall and Flooding

The heaviest rains associated with Henri occurred in extreme southeastern New York and northern New Jersey (Table 3, Fig. 5) where rainfall totals ranged from 5 to nearly 10 inches. The highest amount was 9.88 inches which fell in Greenwood Lake, New York. A total of 9.56 inches was recorded in Brooklyn, New York.

Flooding was extensive, particularly in New Jersey, New York, and Connecticut. Helmetta, in central New Jersey, was especially hard hit where some 200 residents had to seek higher ground. A team of police, firefighters and other emergency responders rescued nearly 100 people from floods in Newark, New Jersey. Waist-deep flooding was reported in Brooklyn, New York. Considerable disruption of roadways due to flooding was noted in the above three states.

Tornadoes

There were 3 tornadoes associated with Henri, in Marlborough, Bolton, and Stow Massachusetts. All of them were small, weak, and short-lived with path widths of 50 m or less and path lengths of 0.75 n mi or less. All were rated EF-0, caused no casualties, and resulted in little or no damage.

CASUALTY AND DAMAGE STATISTICS

Henri was responsible for two direct fatalities in the United States. Two family members (a 50-year old father and 28-year old son) drowned on 18 August after being caught in a rip current near a pier in Oak Island, North Carolina.

Flooding was the most significant impact from Henri's landfall. Wind damage appeared to be mostly downed trees in Rhode Island, Massachusetts, Connecticut, southeastern New York, and New Jersey.

More than 140,000 homes across Connecticut, Rhode Island, Massachusetts and New York were left without power after Henri's passage.

According to the National Centers for Environmental Information, Henri caused an estimated \$700 million in damage in the United States.

FORECAST AND WARNING CRITIQUE

Genesis

Henri's formation was not well predicted. The system from which it formed was not mentioned in the Tropical Weather Outlook (TWO) until just 18 h prior to genesis, with a low (<40%) chance of development (Table 4). The disturbance's formation chances never reached the medium or high categories in the TWO before genesis occurred. Henri's non-tropical origin and a lack of global model support for genesis were probably significant reasons for the poor official forecasts of Henri's development.

Track

A verification of NHC official track forecasts for Henri is given in Table 5a. Official track forecast errors were lower than the mean official errors for the previous 5-yr period at the 36-through 60-h forecast intervals, but greater than the long-term averages at all other forecast intervals. The climatology and persistence forecast errors (OCD5) were greater than average at all intervals, which is perhaps not surprising since Henri moved on an unusual track, and the high OCD5 errors suggested more difficult than normal track forecasts. The official forecasts (Fig. 6) made during the earlier portion of Henri's existence, through 1200 UTC 19 August, had a right bias and failed to show the center reaching the coast of New England. Later on, most of the official forecasts made after 1200 UTC 20 August exhibited a left bias and took Henri too far west and over Long Island.

A homogeneous comparison of the official track errors with selected guidance models for Henri is given in Table 5b. The consensus guidance, TVCA, TVCX, and TVDG all had lower mean errors than the official forecasts at 12 through 120 h. Among the individual models, the U.K. Met. Office model (EGRI), was one of the best, if not the best, performer at all forecast intervals, and had comparable or lower mean errors than the official forecasts at all intervals. The HWRF and HMON models also did well at most forecast intervals.

Intensity

A verification of NHC official intensity forecasts for Henri is given in Table 6a. Official intensity forecast errors were below the mean official errors for the previous 5-yr period at 12 through 60 h, and higher than the long-term means at 72 through 120 h. A homogeneous comparison of the official intensity errors with selected guidance models is given in Table 6b. The simple and corrected consensus models had mean errors that were mostly lower than the official forecasts at all forecast intervals, and DSHP and LGEM were also good performers. In general,

the official forecasts (Fig. 7) called for Henri to be a hurricane at landfall in the northeast U.S., which turned out to be incorrect.

Storm Surge Forecasts and Warnings

Storm surge watches and warnings associated with Henri are given in Table 7 and illustrated in Fig. 8. A Storm Surge Watch was first issued for portions of the coasts of New York, Connecticut, Rhode Island, and Massachusetts at 0900 UTC 20 August for the possibility of significant storm surge inundation. Portions of the watch area were then upgraded to a Storm Surge Warning at 2100 UTC 20 August. Storm surge inundation of 3 ft or greater above normally dry ground (which NHC uses as a first-cut threshold for the storm surge watch/warning) occurred within isolated portions of the Storm Surge Warning area (Fig. 6). Only one instrument in the region, a USGS tide gauge at Greenport, New York, recorded a peak water level above 3 ft MHHW, but storm surge simulation hindcasts indicate that at least 3 ft of inundation above ground level occurred along portions of the north shore of Long Island and the coast of Connecticut. Sustained tropical-storm-force winds are estimated to have reached the area where 3 ft or greater above ground level occurred around 1200 UTC 22 August, 51 h and 39 h after the Storm Surge Watch and Warning, respectively, were issued.

The initial storm surge inundation forecast, issued with the Storm Surge Watch at 0900 UTC 20 August, was 3 to 5 ft above normally dry ground somewhere between Watch Hill, Rhode Island, and Sagamore Beach, Massachusetts, including Narragansett Bay, Buzzards Bay, Vineyard Bay, Nantucket Sound, and Cape Cod Bay. At that time, Henri was forecast to make landfall in the vicinity of Rhode Island or southeastern Massachusetts as a category 1 hurricane. By 0300 UTC 21 August, 3 to 5 ft of inundation was forecast to occur farther west along the coasts of Long Island and Connecticut as well, commensurate with a westward shift in Henri's forecast track and the continued expectation of landfall as a category 1 hurricane. Since Henri weakened more than expected during its approach to the coast and made landfall as a tropical storm, the storm surge inundation forecasts ended up being slightly too high, with observations and post-storm model simulations suggesting that the peak inundation was 3 to 4 ft above normally dry ground.

Wind Watches and Warnings

Wind watches and warnings associated with Henri are given in Table 8. A Hurricane Watch was issued at 0900 UTC 20 August and a Hurricane Warning was issued at 2100 UTC 20 August for a portion of the northeastern U.S. coast. The Hurricane Warning proved to be unnecessary, since Henri was a tropical storm at landfall. However, the Hurricane Watch and Warning provided about 51 and 39 h of lead time, respectively, before the arrival of tropical storm conditions on the coast.

Impact-Based Decision Support Services (IDSS) and Public Communication

The National Hurricane Center (NHC) began communication with emergency managers on 18 August when Henri was a tropical storm southwest of Bermuda through its landfall in Rhode

Island on 22 August. This communication included briefings with FEMA Headquarters and FEMA Regions 1 and 2, as well as briefings for New York, New Jersey, New York City and the Region 1 states. These decision support briefings were coordinated through the FEMA Hurricane Liaison Team, embedded at the NHC.

The NHC television media pool was activated on 21 and 22 August, and provided a total of 65 media briefings on Henri and its potential impacts on those days.

ACKNOWLEDGMENTS

Much of the observed data in this report came from Post Tropical Cyclone Reports issued by NWS Weather Forecast Offices (WFOs) in Norton, Massachusetts, Upton, New York, and Albany, New York. Data was also provided by the NOAA National Data Buoy Center, NOS Center for Operational Oceanographic Products and Services (CO-OPS) and the USGS.

John P. Cangialosi produced the track map. David Roth of the NOAA Weather Prediction Center produced the rainfall map. Matthew Green and Tiffany O'Connor provided the IDSS briefing information, and Dennis Feltgen provided the media briefing summary.

Table 1. Best track for Hurricane Henri, 15–23 August 2021.

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
15 / 0000	35.8	63.4	1014	25	low
15 / 0600	35.4	63.1	1012	25	"
15 / 1200	34.8	62.8	1012	25	"
15 / 1800	34.1	62.7	1011	25	tropical depression
16 / 0000	33.4	62.7	1010	30	"
16 / 0600	32.5	62.7	1010	30	"
16 / 1200	31.6	62.7	1010	30	"
16 / 1800	31.1	62.9	1009	35	tropical storm
17 / 0000	30.8	63.1	1008	40	"
17 / 0600	30.6	63.3	1004	45	"
17 / 1200	30.4	63.6	1004	45	"
17 / 1800	30.3	63.9	1000	55	"
18 / 0000	30.2	64.5	998	55	"
18 / 0600	30.1	65.3	998	55	"
18 / 1200	30.0	66.2	998	55	"
18 / 1800	29.9	67.1	995	60	"
19 / 0000	29.7	68.0	995	60	"
19 / 0600	29.5	69.0	995	60	"
19 / 1200	29.5	70.0	995	60	"
19 / 1800	29.6	71.0	999	55	"
20 / 0000	29.7	72.0	997	55	"
20 / 0600	29.9	72.9	995	55	"
20 / 1200	30.1	73.6	995	55	"
20 / 1800	30.8	73.8	994	60	"
21 / 0000	31.6	73.7	993	60	"
21 / 0600	32.5	73.4	993	60	"
21 / 1200	33.6	72.7	991	65	hurricane
21 / 1800	35.4	71.8	990	65	"
22 / 0000	37.6	70.9	988	65	"
22 / 0600	39.4	71.0	986	65	"

Date/Time (UTC)	Latitude (°N)	Longitude (°W)	Pressure (mb)	Wind Speed (kt)	Stage
22 / 1200	40.7	71.3	986	55	tropical storm
22 / 1520	41.2	71.6	987	55	"
22 / 1615	41.3	71.8	988	55	"
22 / 1800	41.5	72.0	991	40	"
23 / 0000	41.8	73.0	1000	30	tropical depression
23 / 0600	41.7	74.4	1005	25	"
23 / 1200	41.6	74.2	1005	25	"
23 / 1800	41.5	73.8	1005	25	low
24 / 0000	41.4	72.7	1006	20	"
24 / 0600	41.9	71.2	1006	20	"
24 / 1200	42.2	69.6	1007	20	"
24 / 1800	42.3	67.3	1008	25	"
25 / 0000					dissipated
22 / 0600	39.4	71.0	986	65	maximum winds and minimum pressure
22 / 1520	41.2	71.6	987	55	landfall on Block Island, Rhode Island
22 / 1615	41.3	71.8	988	55	landfall near Westerly, Rhode Island

Table 2. Selected ship reports with winds of at least 34 kt for Hurricane Henri, 15–23 August 2021.

Date/Time (UTC)	Ship call sign	Latitude (°N)	Longitude (°W)	Wind dir/speed (kt)	Pressure (mb)
20 / 0300	TCZF2	35.0	71.7	250 / 36	1016.8
20 / 1100	TCZF2	35.6	69.3	250 / 50	1016.8
22 / 1500	KAQP	41.4	70.8	130 / 40	1003.2

[illegible]

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) ^c	Storm tide (ft) ^d	Estimated Inundation (ft) ^e	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)				
Stony Brook (EW5678) (40.91N 73.12W)			22/1426	34	46				
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Brooklyn 3.1 NW (NY-KN-25) (40.68N 73.99W)									9.56
Greenwood Lake 3SW (NY-OR-19) (41.19N 74.33W)									9.88
Herricks 1 WNW (NY-NS-66) (40.76N 73.68W)									7.25
Howard Beach 0.4 NNW (NY-QN-33) (40.66N 73.84W)									7.68
Little Neck 0.3 SE (NY-QN-39) (40.76N 73.73W)									8.07
New York 7 NNW (NY-NY-82) (40.76N 73.99W)									9.12
US Geological Survey (USGS) Storm Tide Sensors									
Great Kills (KILN6) (40.54N 74.13W)						1.82	3.83	1.5	
Lattingtown (LATN6) (40.91N 73.59W)							5.20	1.5	
Orient (ORIN6) (41.14N 72.31W)						2.13	2.75	1.5	
Point Lookout (40.59N 73.58W)						2.02	3.22	1.2	
Ponquogue (SHIN6) (40.85N 72.50W)						1.54	2.88	1.5	
Riverhead (PRIN6) (40.92N 72.64W)						2.57	3.07	1.8	
Sands Point (40.87N 73.71W)							5.69	2.0	
Sayville (SAYN6) (40.72N 73.09W)						1.59	1.95	1.2	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) ^c	Storm tide (ft) ^d	Estimated Inundation (ft) ^e	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)				
Colchester (CT-NL-70) (41.58N 72.32W)									5.35
Hebron 1.6 SW (CT-TL-29) (41.64N 72.39W)									5.62
Hebron 5.3 NW (CT-TL-18) (41.72N 72.43W)									5.94
Manchester (CT-HR-52) (41.79N 72.52W)									5.46
Manchester 0.4 ENE (CT-HR-100) (41.78N 72.51W)									5.78
USGS Wave Height Sensors									
Branford (CTNEW04671) (41.26N 72.82W)							4.77	1.8	
East Lyme (CTNEW04671) (41.26N 72.82W)							2.69	1.4	
Greenwich (CTFAI04806) (41.00N 73.66W)							5.84	2.1	
Greenwich (CTFAI15448) (41.01N 73.63W)							5.69	1.9	
Groton (CTNEW00026) (41.34N 72.04W)							2.44	1.3	
New Haven (CTNEW04669) (41.30N 72.95W)							4.98	1.8	
Old Lyme (CTMID04510) (41.28N 72.28W)							2.92	1.4	
Old Saybrook (CTMID04661) (41.28N 72.39W)							3.33	1.4	
Stonington (CTNEW04511) (41.34N 71.91W)							2.36	1.2	
Stonington (CTNEW04512) (41.33N 71.91W)							2.49	1.3	
Waterford (CTNEW04508) (41.33N 72.18W)							2.44	1.2	

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) ^c	Storm tide (ft) ^d	Estimated Inundation (ft) ^e	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)				
Westport (CTFAI00005) (41.15N 73.36W)							5.37	1.7	
Rhode Island									
International Civil Aviation Organization (ICAO) Sites									
Block Island (KBID) (41.17N 71.58W)	22/1451	989.5	22/1415	32 ⁱ	48 ⁱ				
Newport (KUJU) (41.53N 71.28W)	22/1553	1000.2	22/1530	29	42				
Providence (KPVD) (41.72N 71.43W)	22/1651	1001.9	22/1540	30	41				
Smithfield (KSFZ) (41.92N 71.49W)	22/1656	1004.5	22/1356	23	34				
Westerly (KWST) (41.35N 71.80W)	22/1553	993.6	22/1418	26	39				
Hydrometeorological Automated Data System (HADS) Sites (NWS)									
Kingston 1W (PFKR1) (41.48N 71.54W)			22/1600		34				
Prudence Island (NAXR1) (41.64N 71.34W)	22/1615	1000.7	22/1545	29	40				
National Ocean Service (NOS) Sites									
Conimicut Light (CPTR1) (41.72N 71.35W)	22/1606	1001.6				2.31		1.7	
Newport (NWPR1) (41.50N 71.33W) (8m)	22/1548	999.4	22/1554	29 (8-min)	42	2.06		1.9	
Potter Cove (PTCR1) (41.64N 71.34W) (9m)	22/1606	1002.2	22/1536	29 (8-min)	40				
Providence (FOXR1) (41.81N 71.40W) (18m)	22/1636	1003.1	22/1554	29 (8-min)	38	2.35		1.7	
Quonset Point (QPTR1) (41.59N 71.41W) (7m)	22/1554	999.6	22/1554	38 (8-min)	49	2.46		1.9	
Weatherflow									
Beavertail (XBVT) (41.45N 71.40W) (12m)	22/1542	992.9	22/1547	36 (1-min)	49				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) ^c	Storm tide (ft) ^d	Estimated Inundation (ft) ^e	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)				
Charlestown 4.7 NNE (RI-WS-45) (41.45N 71.61W)									3.28
South Kingston 4.3 WSW (RI-WS-80) (41.42N 71.60W)									3.14
US Geological Survey (USGS) Water Level Sensors									
Little Compton (RINEW00015) (41.47N 71.19W)							3.49	1.9	
Narragansett (RIWAS00008) (41.38N 71.51W)							3.79	2.3	
USGS Wave Height Sensors									
North Kingstown (RIWAS00012) (41.53N 71.42W)							3.40	1.6	
Portsmouth (RINEW00014) (41.62N 71.24W)							3.46	1.5	
Portsmouth (RINEW04550) (41.56N 71.24W)							3.66	1.8	
Warren (RIBRI00013) (41.73N 71.29W)							3.65	1.5	
Warwick (RIKEN00011) (41.69N 71.39W)							3.61	1.5	
Massachusetts									
International Civil Aviation Organization (ICAO) Sites									
Boston (KBOS) (42.36N 71.01W)	22/1854	1007.6	22/1535	27	34				
Chicopee (KCEF) (42.19N 72.54W)	22/1959	1003.1	22/1833	20	39				
Falmouth (KFMH) (41.66N 70.52W)			22/1545	24	34				
New Bedford (KEWB) (41.68N 70.96W)	22/1553	1004.2	22/1500	23	38				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) ^c	Storm tide (ft) ^d	Estimated Inundation (ft) ^e	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)				
Plymouth (KPYM) (41.91N 70.73W)	22/1652	1007.1	22/1650	23	34				
Vineyard Haven (KMYV) (41.39N 70.61W)	22/1253	1004.1	22/1350	27	39				
Westfield (KBAF) (42.16N 72.72W)	22/1953	1002.5	22/1815	24	34				
Worcester (KORH) (42.27N 71.88W)	22/1854	1004.9	22/1722	23	37				
Coastal-Marine Automated Network (C-MAN) Sites									
Buzzards Bay (BUZM3) (41.40N 71.03W) (25m)	22/1500	1000.3	22/1400	45 (10-min)	57				
National Ocean Service (NOS) Sites									
Borden Flats Light (BLTM3) (41.70N 71.17W) (16m)	22/1618	1003.2	22/1606	27 (8-min)	40				
Chatam, Lydia Cove (CHTM3) (41.69N 69.95W)						1.32		1.7	
Fall River (FRVM3) (41.70N 71.16W)	22/1624	1003.5				2.11		1.7	
Nantucket Island (NTKM3) (41.29N 70.10W)						1.12		1.4	
Woods Hole (BZBM3) (41.52N 70.67W)	22/1348	1004.7				1.79		1.5	
Weatherflow									
Courageous Sailing Center (XCOR) (42.37N 71.05W) (22m)	22/0002	1011.5	22/1537	30 (1-min)	34				
Deer Island (XDER) (42.31N 70.89W) (17m)	22/1917	1005.2	22/1453	32 (1-min)	40				
Dog Bar Breakwater (XDOG) (42.58N 70.67W) (14m)	22/1909	1007.3	22/1257	27 (1-min)	34				
Duxbury (XDUX) (42.06N 70.65W) (12m)	22/1346	1005.1	22/1050	31 (1-min)	41				
Duxbury Bay (DXDB) (42.04N 70.67W) (15m)	22/1632	1005.8	22/1308	30 (1-min)	35				



Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) ^c	Storm tide (ft) ^d	Estimated Inundation (ft) ^e	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)				
Horseneck Beach (XHOR) (41.51N 71.09W) (11m)	22/1450	997.2	22/1500	38 (1-min)	48				
Hull (XHUL) (42.31N 70.89W) (12m)	22/1738	1005.8	22/1202	29 (1-min)	38				
Kalmus (XKAL) (41.63N 70.28W) (10m)	22/1340	1006.1	22/1053	31 (1-min)	37				
Pleasure Bay (XPLB) (42.33N 71.02W) (9m)	22/1541	1005.8	22/1459	35 (1-min)	39				
Revere Beach (XREV) (42.41N 70.99W) (12m)	22/1903	1005.9	22/1552	27 (1-min)	34				
Scituate (XSIT) (42.20N 70.72W) (10m)	22/1802	1005.7	22/1252	26 (1-min)	37				
Squantum (XSQN) (42.28N 71.01W) (16m)	22/1858	1006.6	22/1457	29 (1-min)	39				
Vineyard Haven (XVIN) (41.46N 70.59W) (10m)	22/1246	1001.2	22/1418	33 (1-min)	40				
Waquoit Bay (XWAQ) (41.56N 70.51W) (17m)	22/1314	1004.1	22/1537	26 (1-min)	36				
Wellfleet (XWEL) (41.93N 69.98W) (6m)	22/1415	1005.0	22/1124	31 (1-min)	42				
West Dennis (XWDN) (41.65N 70.17W) (13m)	22/1327	1006.6	22/1407	28 (1-min)	40				
West Island (XWST) (41.58N 70.82W) (10m)	22/1335	1002.5	12/1448	39 (1-min)	45				
Woods Hole Passage Light (XWHL) (41.52N 70.68W) (12m)	22/1501	1001.2	22/1420	41 (1-min)	48				
WeatherSTEM									
Boston College (0258W) (42.33N 71.17W)	22/1930	1001.0	22/1740	24	34				
Public/Other									
Cambridge (CW6612) (42.36N 71.09W)			22/2042	23	36				
Duxbury (EW8920) (42.00N 70.60W)	22/1849	1005.8	22/1259	28	35				
Provincetown (FW5824) (42.07N 70.19W)	22/1917	1007.8	22/1907	25	36				
Rockport (AV086) (42.64N 70.58W)	22/1950	1006.8	22/1315	29	37				
Siasconset (DW0935) (41.28N 69.96W)	22/1330	1006.4	22/1345	25	34				

Location	Minimum Sea Level Pressure		Maximum Surface Wind Speed			Storm surge (ft) ^c	Storm tide (ft) ^d	Estimated Inundation (ft) ^e	Total rain (in)
	Date/time (UTC)	Press. (mb)	Date/time (UTC) ^a	Sustained (kt) ^b	Gust (kt)				
Tauton (FW8220) (41.92N 71.10W)	22/1722	1004.1	22/1507	24	34				
Truro (FW6034) (41.99N 70.01W)	22/1427	1007.1	22/1202	30	40				
Wellfleet (FW3885) (41.94N 69.98W)	22/1426	1007.1	22/1131	33	39				
West Island (DW4230) (41.60N 70.83W)	22/1516	1004.1	22/1500	14	35				
Williamstown (F4085) (42.69N 73.19W)	22/2255	1008.5	22/2105		50				
Woods Hole (FW2970) (41.53N 70.68W)	22/1530	1005.8	22/1931	20	36				
Community Collaborative Rain, Hail and Snow Network (CoCoRaHS) Sites									
Westhampton 0.4 WNW (MA-HS-45) (42.30N 72.77W)									4.59
Westhampton 1.8 SW (MA-HS-2) (42.28N 72.79W)									5.54
US Geological Survey (USGS) Water Level Sensors									
Bourne (MABAR04546) (41.75N 70.62W)							3.52	1.7	
Chatam (MABAR04531) (41.67N 69.97W)							3.00	1.1	
Fairhaven (MABRI00017) (41.60N 70.84W)							3.22	1.2	
Hyannis (MABAR00028) (41.64N 70.28W)							3.22	1.6	
North Falmouth (MABAR00023) (41.66N 70.62W)							3.29	1.3	
Osterville (MABAR04555) (41.62N 70.40W)							2.93	1.5	

- ^a Date/time is for sustained wind when both sustained and gust are listed.
 - ^b Except as noted, sustained wind averaging periods for C-MAN and land-based reports are 2 min; buoy averaging periods are 8 min.
 - ^c Storm surge is water height above normal astronomical tide level.
 - ^d For most locations, storm tide is water height above the North American Vertical Datum of 1988 (NAVD88). Storm tide is water height above Mean Lower Low Water (MLLW) for NOS stations in Puerto Rico, the U.S. Virgin Islands, and Barbados.
 - ^e Estimated inundation is the maximum height of water above ground. The height of the water above Mean Higher High Water (MHHW) is used as a proxy for inundation, and the wave-filtered water level data was used for USGS instruments.
- .

Table 4. Number of hours in advance of formation associated with the first NHC Tropical Weather Outlook forecast in the indicated likelihood category. Note that the timings for the “Low” category do not include forecasts of a 0% chance of genesis.

	Hours Before Genesis	
	48-Hour Outlook	120-Hour Outlook
Low (<40%)	18	18
Medium (40%-60%)	0	0
High (>60%)		

Table 5a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) track forecast errors (n mi) for Hurricane Henri, 15–23 August 2021. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	23.9	37.6	45.6	45.9	61.9	97.5	183.7	295.6
OCD5	48.6	129.0	204.3	249.3	309.8	370.2	450.7	525.9
Forecasts	29	27	25	23	21	19	15	11
OFCL (2016-20)	23.9	36.3	49.1	63.9	79.0	94.1	128.1	169.7
OCD5 (2016-20)	45.1	97.2	157.2	216.7	271.1	325.4	414.4	490.0

Table 5b. Homogeneous comparison of selected track forecast guidance models (in n mi) for Hurricane Henri, 15–23 August 2021. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 5a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	23.0	35.5	46.7	47.6	63.3	98.2	175.3	342.6
OCD5	47.6	125.1	218.2	268.0	327.2	373.5	407.7	468.9
GFSI	21.3	32.5	48.6	55.2	68.9	100.8	153.6	221.1
CMCI	29.6	52.4	70.3	89.2	118.0	143.9	250.8	416.1
CTCI	19.6	31.4	48.7	53.1	66.0	96.3	175.3	310.8
NVGI	33.5	57.2	81.1	108.5	143.7	178.5	264.1	517.3
HWFI	28.3	41.3	51.0	46.9	47.6	60.6	136.2	327.0
HMNI	21.3	34.8	52.5	61.9	63.2	78.7	184.8	182.0
EGRI	24.0	34.0	36.5	45.4	61.2	64.1	134.3	200.1
HCCA	20.3	31.4	39.6	36.6	45.0	75.0	183.1	377.3
FSSE	19.8	28.3	37.6	46.5	68.2	98.7	168.1	310.5
AEMI	27.3	45.6	61.4	68.9	109.3	150.8	231.4	403.4
TVCA	22.6	35.4	44.1	43.7	51.6	72.8	139.4	261.4
TVCX	22.4	36.8	45.5	45.3	55.9	76.3	141.4	245.8
TVDG	22.1	34.8	42.9	45.3	53.1	74.4	139.4	227.4
TABS	48.9	116.6	202.2	265.3	312.2	368.8	494.8	1021.9
TABM	35.5	63.6	107.1	132.8	153.2	190.6	200.0	295.0
TABD	37.9	68.8	101.6	124.4	160.4	228.6	381.7	642.4
Forecasts	23	22	21	19	17	16	12	6

Table 6a. NHC official (OFCL) and climatology-persistence skill baseline (OCD5) intensity forecast errors (kt) for Hurricane Henri, 15–23 August 2021. Mean errors for the previous 5-yr period are shown for comparison. Official errors that are smaller than the 5-yr means are shown in boldface type.

	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	4.0	5.7	8.0	9.8	11.0	12.4	16.0	21.8
OCD5	4.6	6.7	9.4	10.6	11.5	11.5	12.7	14.5
Forecasts	29	27	25	23	21	19	15	11
OFCL (2016-20)	5.4	8.0	9.6	10.9	11.5	12.1	13.3	14.5
OCD5 (2016-20)	7.0	11.0	14.3	16.8	18.3	19.7	21.7	23.0

Table 6b. Homogeneous comparison of selected intensity forecast guidance models (in kt) for Hurricane Henri, 15–23 August 2021. Errors smaller than the NHC official forecast are shown in boldface type. The number of official forecasts shown here will generally be smaller than that shown in Table 6a due to the homogeneity requirement.

Model ID	Forecast Period (h)							
	12	24	36	48	60	72	96	120
OFCL	4.4	5.8	8.0	10.2	11.9	13.4	19.2	26.2
OCD5	4.7	7.2	10.0	12.1	12.9	13.4	14.0	18.9
HWFI	4.3	5.1	7.5	13.2	17.4	20.3	26.7	35.8
HMNI	4.0	7.0	6.9	7.7	9.1	11.9	18.1	25.1
DSHP	4.5	6.0	6.5	7.4	7.9	9.3	18.2	23.1
LGEM	4.5	5.9	6.2	6.8	7.4	8.7	15.9	18.6
ICON	3.5	4.0	4.4	5.7	7.3	8.3	12.4	19.6
IVCN	3.2	3.9	4.9	7.1	9.6	11.1	16.3	23.9
IVDR	2.9	3.9	4.9	7.3	10.2	11.9	16.2	24.1
CTCI	3.7	5.7	7.8	13.4	19.6	23.6	34.5	41.1
GFSI	4.3	6.3	8.5	10.2	12.7	14.4	20.3	23.5
HCCA	3.1	4.1	5.5	7.4	9.9	12.1	17.3	28.2
FSSE	3.1	3.6	5.3	7.8	10.1	11.5	16.1	21.5
Forecasts	25	24	22	20	18	16	12	8

Table 7. Storm surge watch and warning summary for Hurricane Henri, 15–23 August 2021.

Date/Time (UTC)	Action	Location
20 / 0900	Storm Surge Watch issued	South shore of Long Island from East Rockaway Inlet to Montauk Point; North shore of Long Island from Kings Point to Montauk Point; Kings Point, NY to Sagamore Beach, MA; Nantucket, Martha's Vineyard, and Block Island
20 / 1500	Storm Surge Watch extended	West of Kings Point to Flushing, NY, including adjacent portions of the East River
20 / 2100	Storm Surge Warning issued	South shore of Long Island from Mastic Beach to Montauk Point; North shore of Long Island from Oyster Bay to Montauk Point; Greenwich, CT to Chatham, MA; Nantucket, Martha's Vineyard, and Block Island
21 / 0300	Storm Surge Warning extended	Oyster Bay to Flushing, NY; Flushing to Greenwich, CT
22 / 1500	Storm Surge Watch discontinued	South shore of Long Island from East Rockaway Inlet to west of Mastic Beach; north of Chatham to Sagamore Beach, MA
22 / 1800	Storm Surge Warning discontinued	All

Table 8. Wind watch and warning summary for Hurricane Henri, 15–23 August 2021.

Date/Time (UTC)	Action	Location
16 / 0300	Tropical Storm Watch issued	Bermuda
18 / 0900	Tropical Storm Watch discontinued	All
20 / 0900	Tropical Storm Watch issued	East Rockaway Inlet to Fire Island Inlet
20 / 0900	Tropical Storm Watch issued	Port Jefferson Harbor to New Haven
20 / 0900	Hurricane Watch issued	Fire Island Inlet to Port Jefferson Harbor
20 / 0900	Hurricane Watch issued	New Haven to Sagamore Beach
20 / 0900	Hurricane Watch issued	Nantucket Island
20 / 0900	Hurricane Watch issued	Martha's Vineyard
20 / 0900	Hurricane Watch issued	Block Island
20 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	East Rockaway Inlet to Fire Island Inlet
20 / 2100	Tropical Storm Watch changed to Tropical Storm Warning	Port Jefferson Harbor to New Haven
20 / 2100	Hurricane Watch changed to Hurricane Warning	Fire Island Inlet to Port Jefferson Harbor
20 / 2100	Tropical Storm Watch issued	Manasquan Inlet to East Rockaway Inlet
20 / 2100	Hurricane Watch modified to	Watch Hill to Sagamore Beach
20 / 2100	Hurricane Warning issued	New Haven to Watch Hill

Date/Time (UTC)	Action	Location
21 / 0300	Tropical Storm Watch changed to Tropical Storm Warning	Manasquan Inlet to East Rockaway Inlet
21 / 0300	Tropical Storm Warning issued	Watch Hill to Woods Hole
21 / 0300	Tropical Storm Warning issued	Martha's Vineyard
21 / 0300	Tropical Storm Warning issued	Block Island
21 / 0600	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
21 / 0900	Hurricane Watch changed to Tropical Storm Warning	Martha's Vineyard
21 / 0900	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
21 / 0900	Hurricane Watch modified to	Watch Hill to Westport
21 / 0900	Hurricane Watch discontinued	Nantucket Island
21 / 1200	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
21 / 1500	Tropical Storm Warning changed to Hurricane Warning	Block Island
21 / 1500	Tropical Storm Warning discontinued	Watch Hill to Woods Hole
21 / 1500	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
21 / 1500	Tropical Storm Warning issued	Westport to Chatham
21 / 1500	Tropical Storm Warning issued	Nantucket Island
21 / 1500	Hurricane Watch discontinued	All
21 / 1500	Hurricane Warning modified to	New Haven to Westport

Date/Time (UTC)	Action	Location
21 / 1800	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
21 / 2100	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
22 / 0000	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
22 / 0300	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
22 / 0600	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
22 / 0900	Tropical Storm Warning modified to	East Rockaway Inlet to Fire Island Inlet
22 / 1200	Hurricane Warning changed to Tropical Storm Warning	Block Island
22 / 1200	Tropical Storm Warning discontinued	East Rockaway Inlet to Fire Island Inlet
22 / 1200	Tropical Storm Warning discontinued	Port Jefferson Harbor to New Haven
22 / 1200	Tropical Storm Warning modified to	Manasquan Inlet to Chatham
22 / 1200	Tropical Storm Warning modified to	Manasquan Inlet to Chatham
22 / 1200	Hurricane Warning discontinued	All
22 / 1500	Tropical Storm Warning modified to	East Rockaway Inlet to Chatham
22 / 2100	Tropical Storm Warning discontinued	All

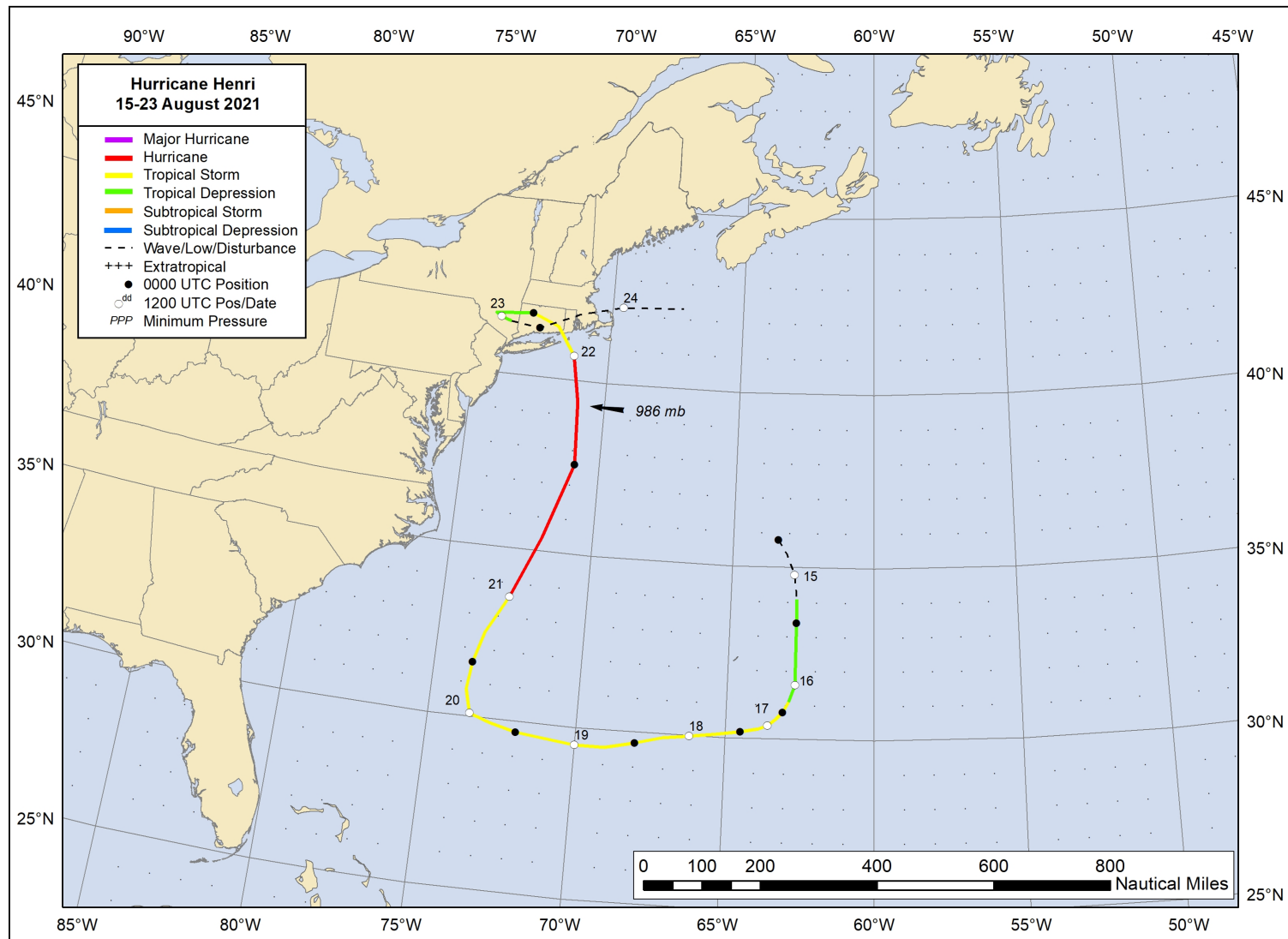


Figure 1. Best track positions for Hurricane Henri, 15–23 August 2021. Track over the United States is partially based on analyses from the NOAA Weather Prediction Center.

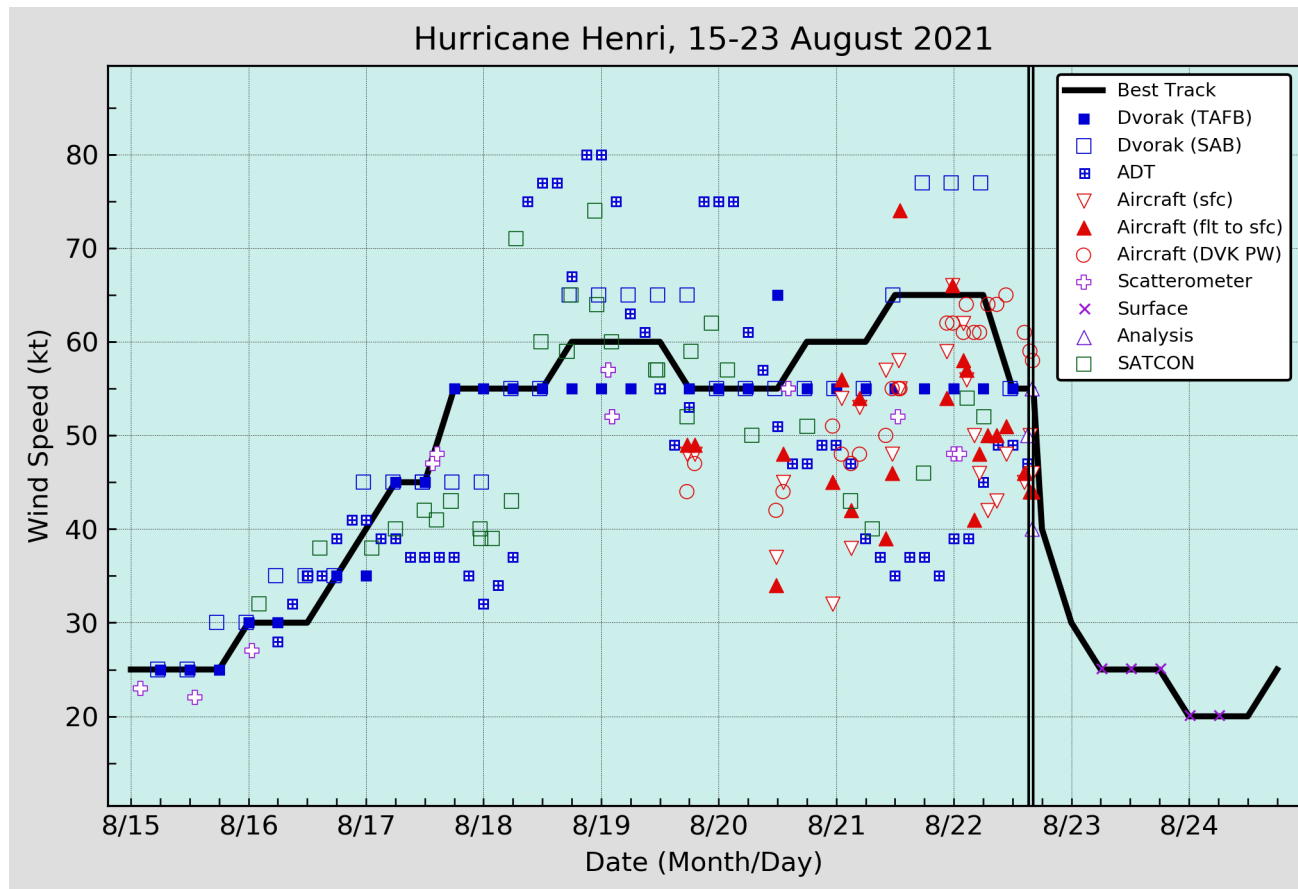


Figure 2. Selected wind observations and best track maximum sustained surface wind speed curve for Hurricane Henri, 15–23 August 2021. Aircraft observations have been adjusted for elevation using 90%, 80%, and 80% adjustment factors for observations from 700 mb, 850 mb, and 1500 ft, respectively. Dropwindsonde observations include actual 10 m winds (sfc), as well as surface estimates derived from the mean wind over the lowest 150 m of the wind sounding (LLM). Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

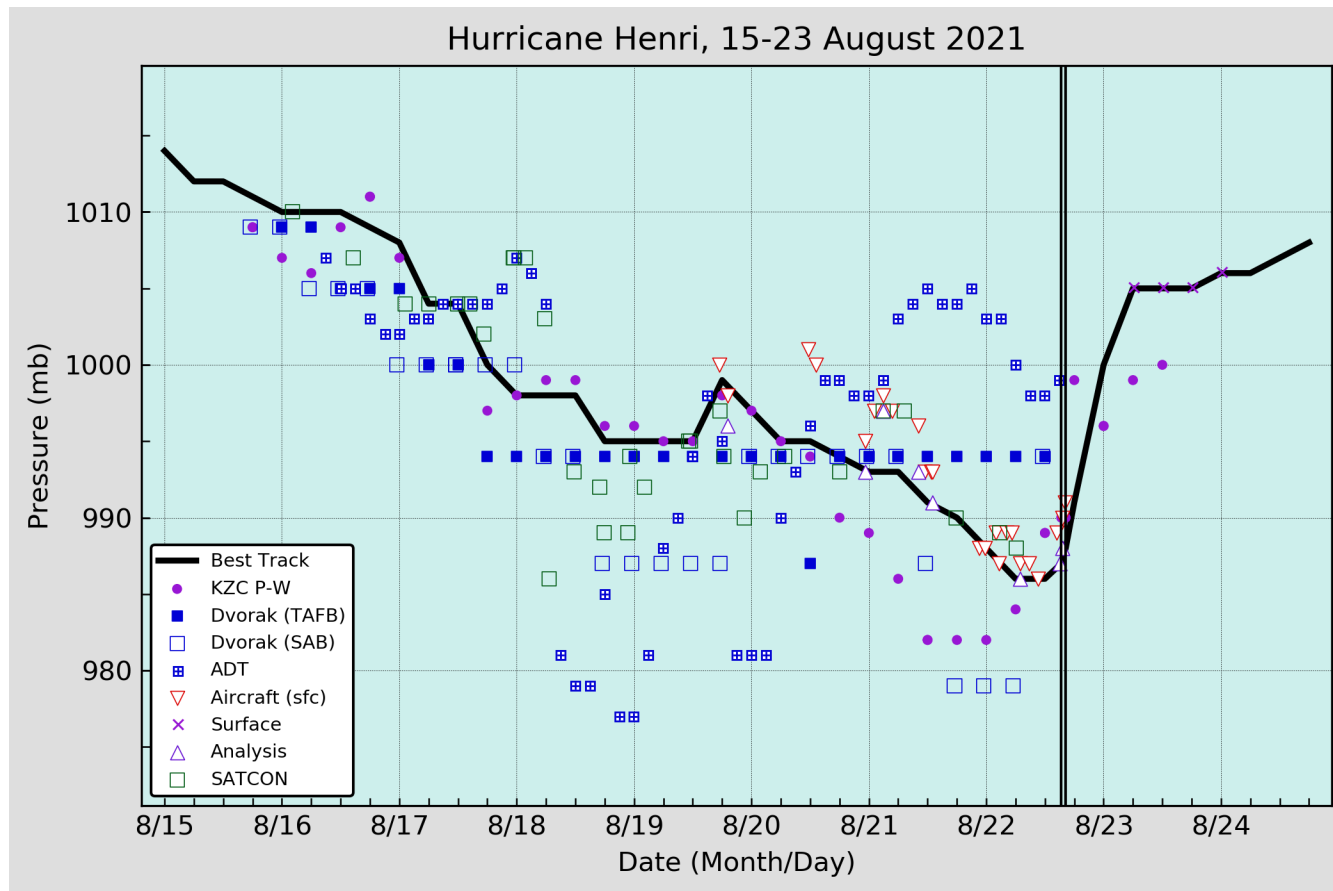


Figure 3. Selected pressure observations and best track minimum central pressure curve for Hurricane Henri, 15–23 August 2021. Advanced Dvorak Technique estimates represent the Current Intensity at the nominal observation time. SATCON intensity estimates are from the Cooperative Institute for Meteorological Satellite Studies. KZC P-W refers to pressure estimates derived using the Knaff-Zehr-Courtney pressure-wind relationship. Dashed vertical lines correspond to 0000 UTC, and solid vertical lines correspond to landfalls.

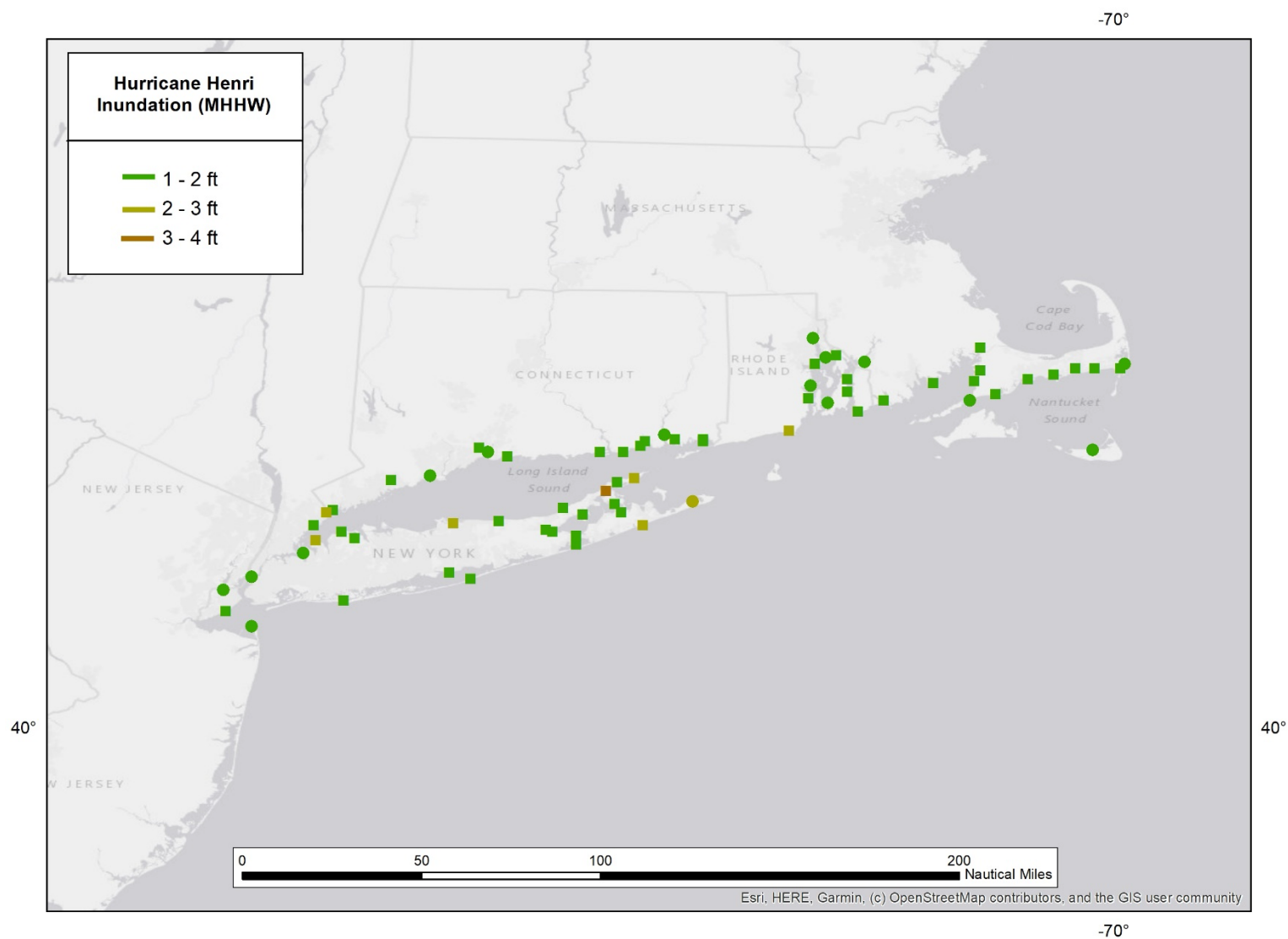


Figure 4. Maximum water levels measured from NOS tide gauges (circles) and USGS water level and wave height sensors (squares) during Hurricane Henri. Water levels are referenced as feet above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline.

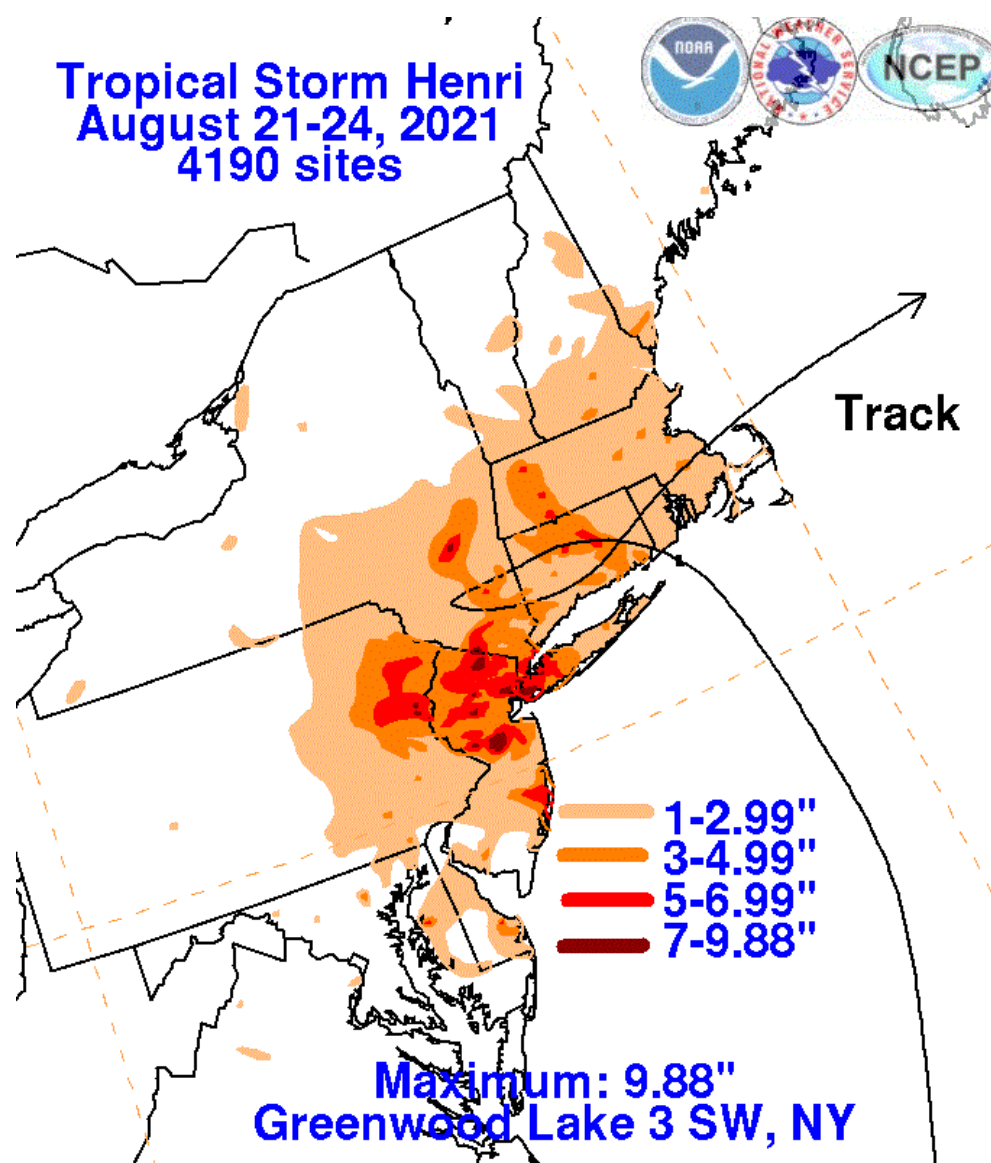


Figure 5. Henri rainfall totals (inches). Figure courtesy of David Roth, NOAA Weather Prediction Center.

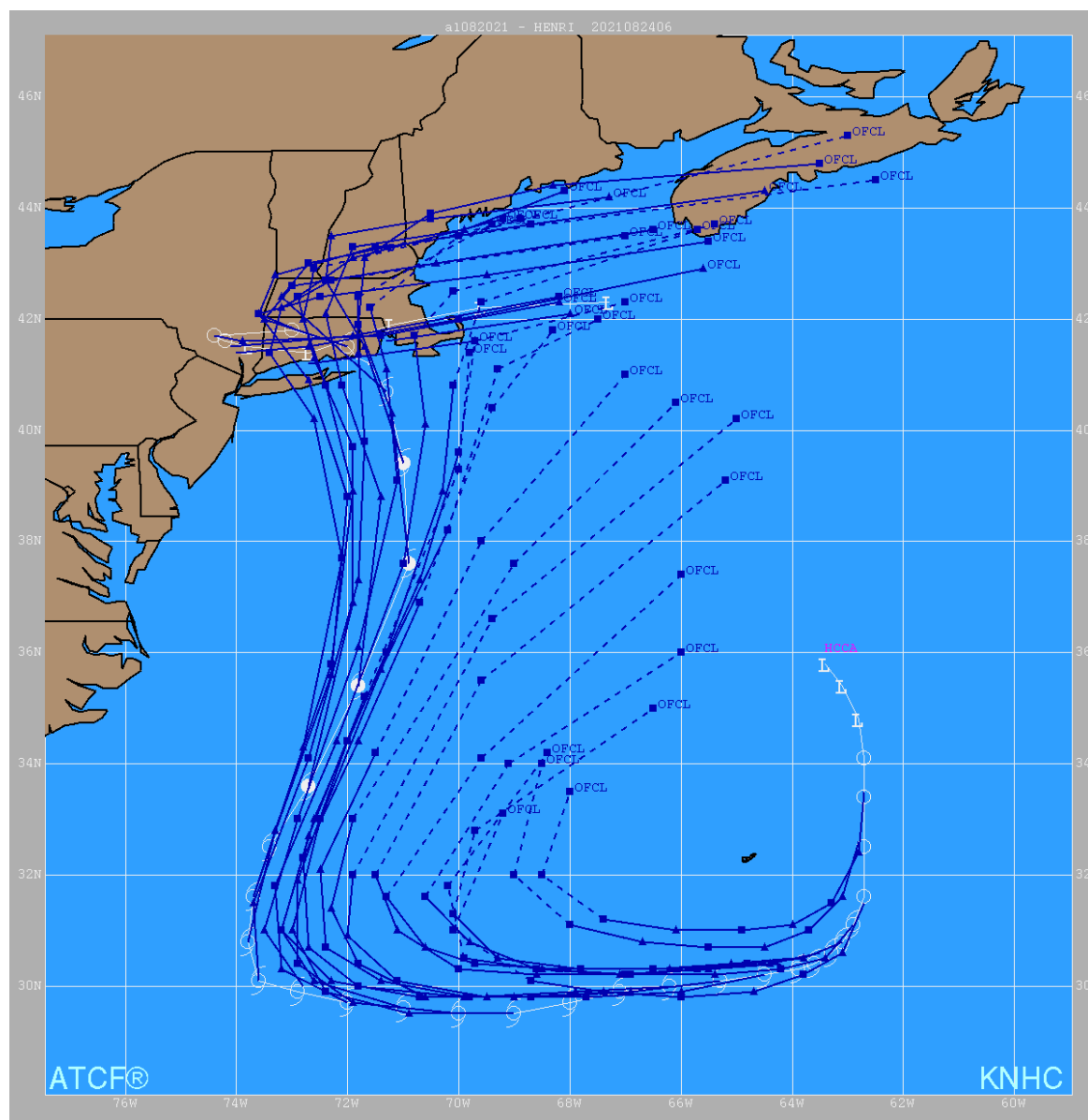


Figure 6. Official track forecasts for Hurricane Henri from 0000 UTC 16 August to 0000 UTC 23 August. The best track is shown in white.

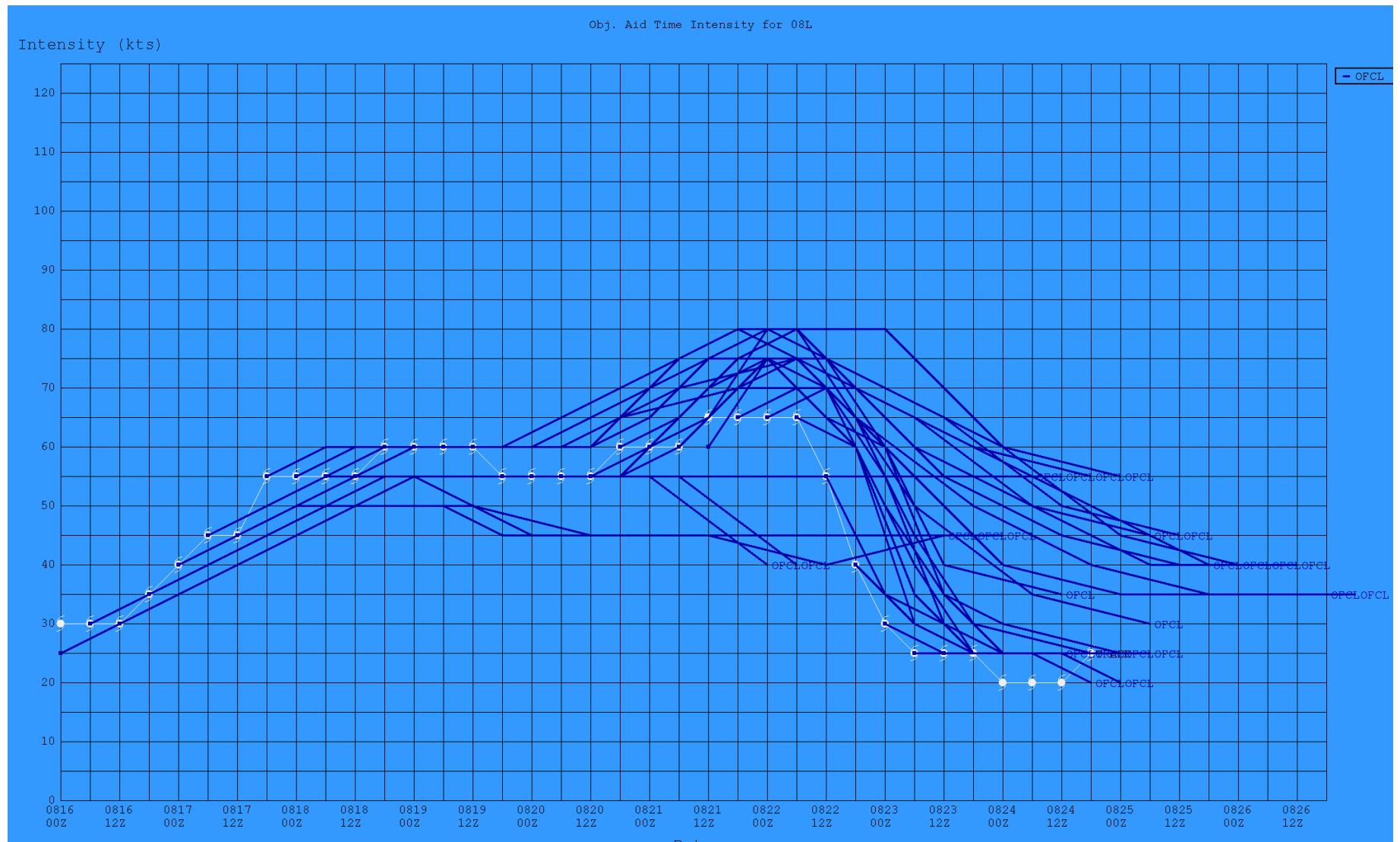


Figure 7. Official intensity forecasts (kt) for Hurricane Henri from 0000 UTC 16 August to 0000 UTC 23 August. The best track intensity (kt) is shown in white.

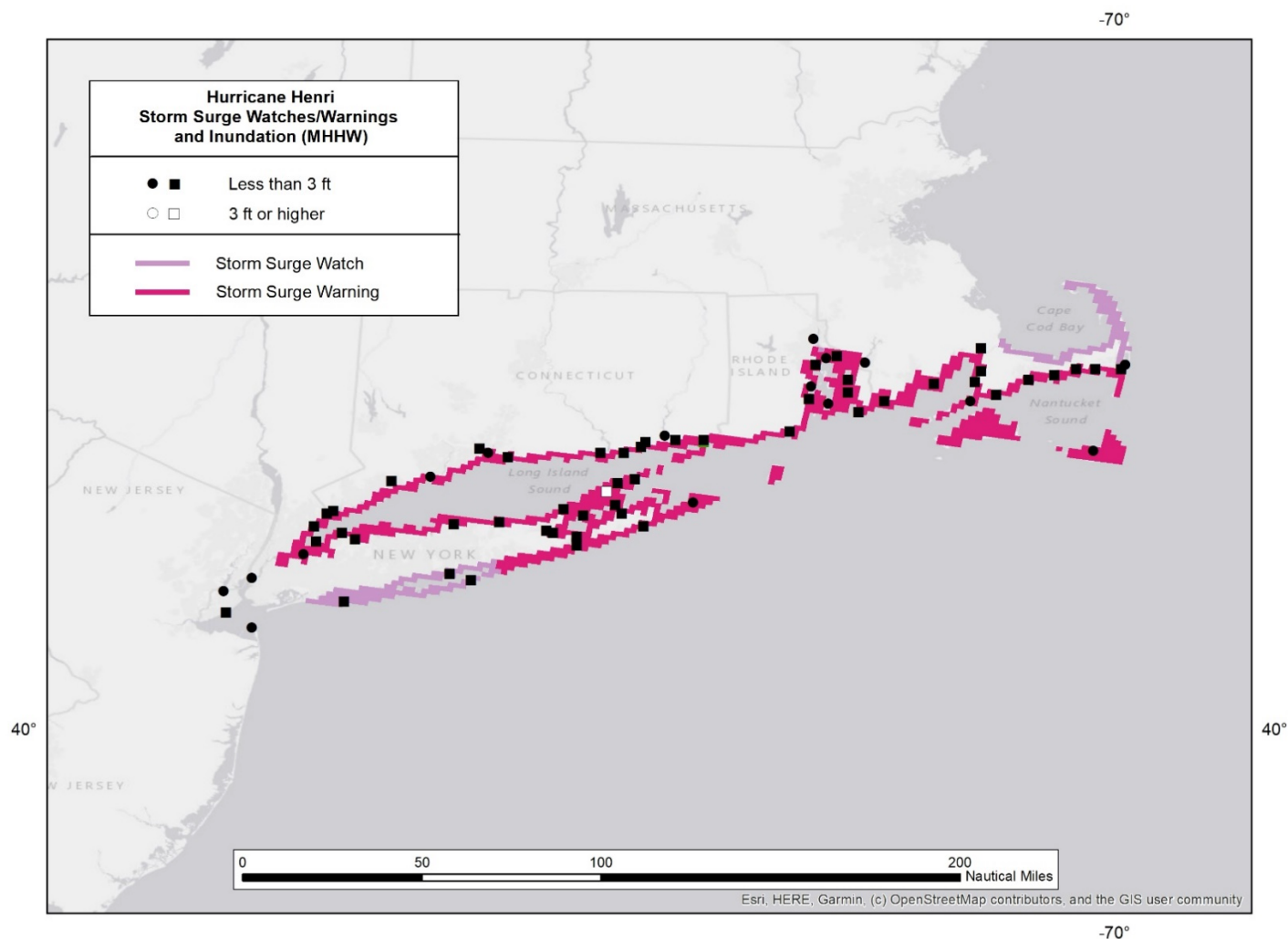


Figure 8. Maximum water levels measured during Hurricane Henri from tide gauges (circles) and USGS water level sensors (squares), and areas covered by storm surge watches (lavender) and warnings (magenta). Water levels are referenced as feet above Mean Higher High Water (MHHW), which is used as a proxy for inundation (above ground level) on normally dry ground along the immediate coastline. Black markers denote water levels less than 3 ft above ground level, and white markers denote water levels 3 ft or higher above ground level.